(6.20)

where *G* is the gravitational constant and *M* the earth's mass. Calculations yield *R = 42200km*, which corresponds to an altitude of 35700km. This altitude greatly exceeds that of the ionosphere, requiring satellite transmitters to use frequencies that pass through it. Of great importance in satellite communications is the transmission delay. The time for electromagnetic fields to propagate to a geosynchronous satellite and return is 0.24 s, a significant delay.

Exercise 6.7.1

In addition to delay, the propagation attenuation encountered in satellite communication far exceeds what occurs in ionospheric-mirror based communication. Calculate the attenuation incurred by radiation going to the satellite (one-way loss) with that encountered by Marconi (total going up and down). Note that the attenuation calculation in the ionospheric case, assuming the ionosphere acts like a perfect mirror, is not a straightforward application of the propagation loss formula.

6.8 Noise and Interference

We have mentioned that communications are, to varying degrees, subject to interference and noise. It's time to be more precise about what these quantities are and how they difer.

Interference represents man-made signals. Telephone lines are subject to power-line interference (in the United States a distorted 60 Hz sinusoid). Cellular telephone channels are subject to adjacent-cell phone conversations using the same signal frequency. The problem with such interference is that it occupies the same frequency band as the desired communication signal, and has a similar structure.

Exercise 6.8.1

Suppose interference occupied a different frequency band; how would the receiver remove it?

We use the notation *i (t)* to represent interference. Because interference has man-made structure, we can write an explicit expression for it that may contain some unknown aspects (how large it is, for example).

Noise signals have little structure and arise from both human and natural sources. Satellite channels are subject to deep space noise arising from electromagnetic radiation pervasive in the galaxy. Thermal noise plagues all electronic circuits that contain resistors. Thus, in receiving small amplitude signals, receiver amplifiers will most certainly add noise as they boost the signal's amplitude. All channels are subject to noise, and we need a way of describing such signals despite the fact we can't write a formula for the noise signal like we can for interference. The most widely used noise model is **white noise**. It is defined entirely by its frequency-domain characteristics.

- White noise has constant power at all frequencies.